

Low-Voltage Spatial Light Modulator

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Low-Voltage Spatial Light Modulator

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This project studied the feasibility of a Low-Voltage actuator technology that promises to reduce the switched voltage requirements and linearize the response of spatial light modulators. We created computer models that demonstrate substantial advantages offered by this technology, and fabricated and tested those devices.

SLMs are electro-optic devices for modulating the phase, amplitude or angle of light beams, laser or other. Applications for arrays of SLMs include turbulence correction for high-speed optical communications, imaging through distorting media, input devices for holographic memories, optical manipulation of DNA molecules, and optical computers. Devices based on micro electro-mechanical systems (MEMS) technology have recently become of special interest because of their potential for greatly improved performance at a much lower cost than piezoelectric or liquid crystal based devices. The new MEMS-based SLM devices could have important applications in high-speed optical communication and remote optical sensing, in support of DoD and DOE missions.

Virtually all previously demonstrated MEMS SLMs are based on parallel-plate capacitors where an applied voltage causes a mirror attached to a suspended electrode to move towards a fixed electrode. They require relatively high voltages, typically on the order of 100 V, resulting in (1) large transistor sizes, available only from specialized foundries at significant cost and limiting the amount/sophistication of electronics under each SLM pixel, and (2) large power dissipation/area, resulting in a heat removal issue because of the optical precision required ($\sim 1/50$ -th of a wavelength). The actuator described in this process uses an advanced geometry that was invented at LLNL and is currently still proprietary. The new geometry allows the application of a

bias voltage. This applied bias voltage results in a reduction of the required switched voltage and a linearization of the response curve.

When this advanced actuator is coupled with non-linear springs, the response curve becomes even more linear. The response curve of the springs is tailored to produce an actuator with extremely linear displacement vs. voltage characteristics.

Major Technical Accomplishments

Computer modeling.

We developed both static and dynamic computer models of the advanced geometry actuators. These models allowed us to demonstrate the advantages of this geometry over conventional parallel plate actuators. As shown in figure 2, as the bias voltage on the actuator is increased, the switched voltage requirement decreases and the linearity increases.

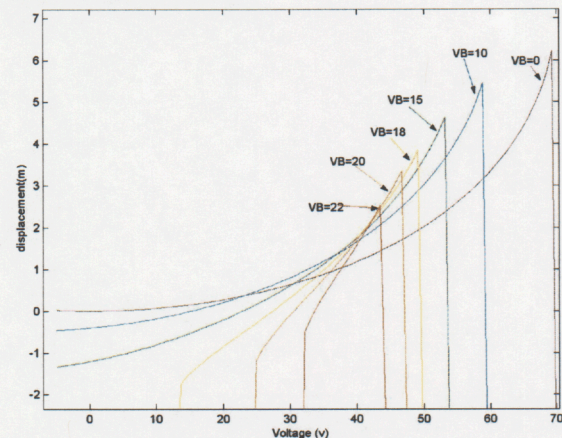


Figure 1 Voltage displacement curve at various bias voltages

Test Devices

Architecture.

One of the major technical advances demonstrated by this project are the ability to fabricate a practical actuator of this type. We designed an architecture that is

compatible with a conventional MEMS foundry. The electrodes are made of polycrystalline silicon deposited in layers on top of an insulating substrate and sandwiched between layers of sacrificial silicon dioxide. The silicon layers are patterned then “released” by etching away the silicon dioxide leaving complex suspended silicon parts.

Design

The other major technical advance of this project is the ability to tune non-linear springs to produce a device with an extremely linear displacement vs. voltage curve. We used optimal design techniques to make 13 test designs. The test designs were optimized for linearity over a set displacement and voltage range. The optimization routines fed different combinations of spring and electrode area parameters into the computer model to find the optimum designs. Figure 4 Shows the displacement vs. voltage curve for an optimized design at its optimum bias voltage and with no bias voltage.

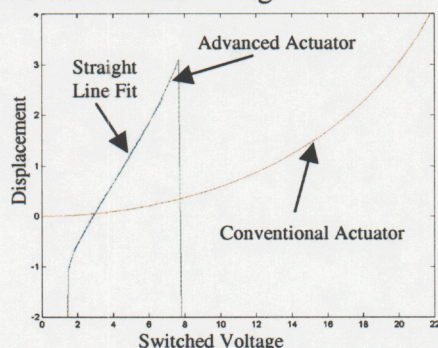


Figure 2. Voltage displacement curve for an optimized device

Fabrication

We submitted designs to a MEMS foundry where they were fabricated in a batch process with designs submitted by several other groups. After fabrication, the parts were “released” and dried at the LLNL clean room. One problem with these fragile polycrystalline silicon parts is that a meniscus can form between parts as they are being dried after the wet chemistry release. This meniscus can pull the parts together; surface forces can then permanently bond

them together in undesirable ways. This was avoided by coating the silicon parts with a self-assembled hydrophobic mono-layer that prevented the formation of the meniscus.

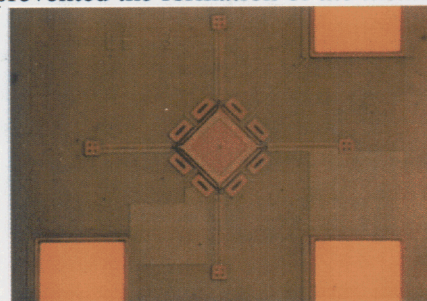


Figure 3. Photograph of test device

Testing

The devices were tested using a ZYGO interferometric microscope. The results show that the actuators behave as predicted; increasing bias voltage on the third electrode increases linearity and reduces required switched voltage.

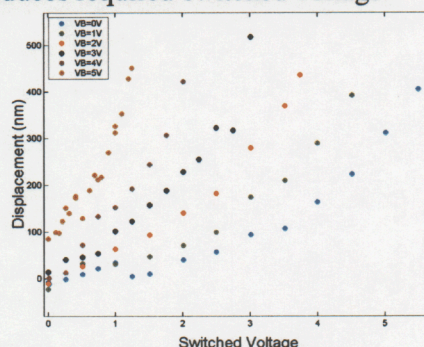


Figure 4. Experimental results.

Future Work

This feasibility study demonstrated an actuator, not an entire system. In contrast several groups have demonstrated 2-electrode systems with integrated mirrors and some are on the verge of demonstrating such systems with integrated electronics.

We are currently seeking funding to make an array of actuators with mirrors and electronics to better compete with these demonstrated, but less sophisticated technologies.